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RESEARCH ARTICLE

The role of shadow economies in ecological footprint quality: empirical evidence from Turkey

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Abstract

The purpose of this research study is to investigate the role of shadow economies in the levels of ecological footprint for the case of Turkey. Annual data set ranging from 1961 to 2014 was used with this respect. The results of this study verify the long-term and positively elastic impact of shadow economic activities on the level of ecological footprint in Turkey; that is, 1 % change in shadow economic activities results in a 1.008% change in ecological footprint in the same direction. This study, therefore, reaches a significant conclusion that in Turkey, shadow economies are long-term and essential drivers of environmental pollution.

Keywords Ecological footprint · Shadow economies · International trade · Environmental pollution · EKC · Turkey

Introduction

In the last two decades, research on environmental issues has gained momentum. To explore the connection between environmental quality and business/economic activities, numerous models have been suggested. This nexus is investigated primarily using the Environmental Kuznets Curve (EKC) hypothesis suggesting an inverted U-shaped relationship between environmental pollution and economic activity. While environmental quality is measured using various indices such as carbon dioxide (CO_2), sulfur dioxide (SO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6), business/economic activity as measured by gross domestic product (GDP) is linking economic growth with environmental degradation (Biswas et al. 2012). Although the link between environmental degradation and formal economic growth is extensively searched in the relevant literature, the role of informal economic activity is not sufficiently studied yet using aggregate data to the best of our knowledge. Informal economic activity is likely to impact environmental quality especially in countries with a high volume of informality. Thus, searching for the link between informal economies and environmental degradation would be an exciting and new research concept.

In both developed and developing countries, informal or shadow economic activities exist; therefore, formal GDP alone cannot represent the whole economic activities. Government bodies aim to reduce the size of informal economic activities in their countries; however, it can be suggested that in many countries, this concept has become a structural economic problem. Thus, any study for the environmental quality and economic growth would be incomplete if the size of informal economies is hidden. This research study seeks to add to the relevant literature by searching the role of informal economic activities on the EKC behavior of Turkey. The motivation in choosing Turkey for such a study is that Turkey is a developing country with a high informality volume in its economy as its economic growth depends on polluting sectors. On the other side, in 2009, Turkey ratified the

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Kyoto Protocol, and in 2016, the Paris Agreement aimed at reducing its rates of greenhouse gas emissions.

As a consequence of these measures, during the period from 2012 to 2016, Turkey reduced its greenhouse gas emissions by 87 million tons; and it was targeted to cut a total of 1 billion 920 million tons of greenhouse gas emissions in the period 2012–2030 (Turkish Ministry of Environment and Urbanization 2017). When evaluating environmental degradation, it should be borne in mind that the rules of government play an important role in regulating and enforcing ecological norms. As the pressure on businesses to manufacture environmentally friendly products rises, their polluting sectors are more likely to switch to informal operations. As stated above, in recent years, Turkey has the ambition to reduce its rates of pollution, and regulatory bodies have therefore implemented more stringent environmental requirements.

This study contributes to the relevant literature not only as a research concept but also means of using a more powerful proxy for pollution. Unlike many previous studies, the current study uses ecological footprint to measure the degree of environmental degradation rather than using carbon dioxide emissions. The ecological footprint is a biologically fertile land and water area required to produce the resources consumed by an individual, community, or activity and to eliminate the waste it generates (Asici and Acar 2018). Therefore, ecological footprint consists not only of greenhouse gases but also of built-up soil, cropland, fishing grounds, forest products, and pastureland (WWF 2012). Katircioglu et al. (2018) argue that using ecological footprint as a proxy for environmental degradation provides more reliable results rather than using the other proxies. Figure 1 plots components of global footprints over the years.

This study is designed as follows: the "Literature review" section provides a review of the relevant literature; the "Model specification and data" section presents model specification, data, and econometric methodology; the "Empirical results" section presents empirical results and discussions, and the "Conclusion" section concludes the study.

Literature review

Like previous studies, Katircioglu (2014a), Danish et al. (2017), Kharbach and Chfadi (2017), and Pata (2018) tested the EKC hypothesis using different econometric techniques such as panel data, parametric and non-parametric analyses, cointegration analysis, causality analysis, and multivariate regression. Some other researchers like Al-Mulali et al. (2015a, 2015b), Ulucak and Bilgili (2018), Jiang et al. (2019b), and Lau et al. (2019) studied a particular country or a group of countries with different time series and regions and added some control factors, including social and political, international trade, energy, and financial indicators.

The empirical findings demonstrate various outcomes and not always as proposed by the EKC hypothesis as an inverted U shape. The available forms can be modeled as monotonous, increasing, monotonous decreasing, inverted U shape, U shape, N shape, and inverted N shape (Abid 2015). Most of the recent literature used panel data from a chosen group of countries or autoregressive-distributed lag (ARDL) models which aim to show the presence of long-run relationships between time-series, for a selected country and CO_2 emissions–economic growth nexus, international trade–CO_2 emissions nexus, and energy consumption–CO_2 emissions nexus. These researches focused on the traditional EKC hypothesis and then included other control variables as shown in Table 1. The studies primarily used CO_2 emissions as a dependent variable to assess the degree of environmental degradation.

The EKC hypothesis that suggests the presence of a U-shaped relationship creates a nexus between economic growth and environmental pollution. According to EKC, with economic growth, environmental degradation rises and reaches a maximum point and then begins to decrease as economic growth increases after reaching the turning point. Three components of environmental pollution and resource use can be examined: scale effect, composition effect, and technique effect (Grossman and Krueger 1991). Scale effect indicates that economic development leads to higher levels of environmental pollution as the increases in output require more input, which creates more emissions. The composition effect shows the structural transition from agricultural manufacturing to the heavily industrialized type of production in the economy. As the economy improves, this time, the transition from heavy industry to light industrial manufacturing and service industries will take place. This transition will result in less pollution and degradation of the environment. Finally, the technique effect will allow the replacement of new and cleaner techniques with outdated and dirtier techniques that will enhance the quality of the environment.

Scholars' attention to the problematic linkage between environmental pollution and economic growth has risen, particularly over the past decade. To find out how this interaction developed, many studies have been conducted using different variables in many countries and regions. Economic growth plays a crucial part in enhancing environmental quality as it does after an income level, according to the EKC hypothesis; the environmental quality will be increased without special measures being imposed. The EKC hypothesis has also been tested using state-level (Apergis et al. 2017; Dong et al. 2017; Jiang et al. 2019a; Wang and Ye 2017; Xu et al. 2019; Zhou and Wang 2018) and household-level data (Cox et al. 2012; Kahn 1998; and Kopnina 2014).

In the literature, greenhouse gas emissions and mainly CO_2 emissions are widely used as a proxy for environmental degradation (Hamit-Haggar 2012; Kalayci and Koksal 2015;

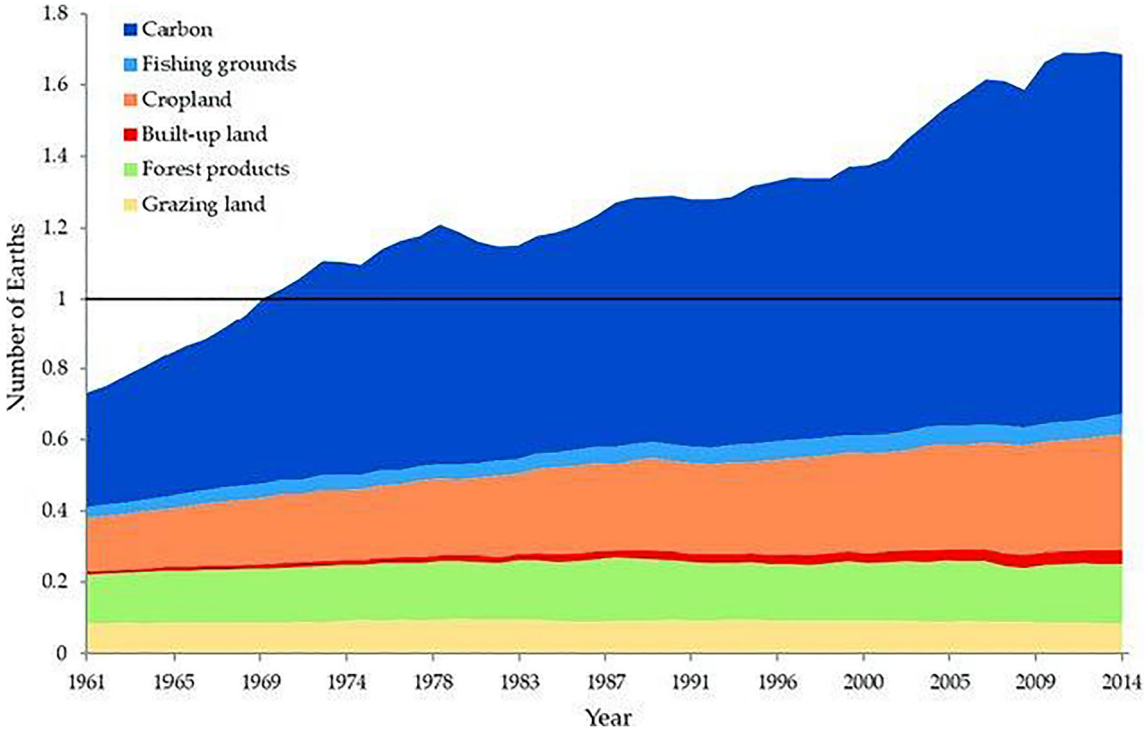


Fig. 1 Ecological footprint of the world by footprint type from 1961 to 2014. Source: Global Footprint Network, National Footprint Accounts 2018th edition

Dogan and Turkekul 2016; Katircioglu and Katircioglu 2018a, 2018b). Except for the research on the USA carried out by Dogan and Turkekul (2016), all the other studies have confirmed the existence of the EKC hypothesis. Some recent studies like Al-Mulali et al. (2015a, 2015b), Destek et al. (2018), Ulucak and Bilgili (2018), He et al. (2019), Mikayilov et al. (2019), and Uddin et al. (2019) used ecological footprint variable as a proxy to assess environmental degradation rather than greenhouse gas emissions alone.

A primary hypothesis of the EKC indicates that the main driver of climate change is energy consumption and, therefore, pollution (Heidari et al. 2015). As the economy expands,

Table 1 Summary of literature review

Authors	Period	Country	Methodology	Variables	EKC
Ang (2007)	1960–2000	France	Johansen, ARDL, VECM	CO_2, EC, GDP, GDP^2, OG	Yes
Pao and Tsai (2010)	1971–2005	BRIC	OLS, VECM Granger	CO_2, EC, GDP, GDP^2	Yes
Shahbaz et al. (2012)	1971–2009	Pakistan	Granger	CO_2, EC, GDP, TO	Yes
Saboori et al. (2012)	1980–2009	Malaysia	ARDL	CO_2, GDP	Yes
Hamit-Haggar (2012)	1990–2007	Canada	OLS, VECM Granger	CO_2, EC, GDP, GDP^2	Yes
Du et al. (2012)	1995–2009	China	Fixed effect (FE) GMM	EC, GDP, GDP^2, IS, TO, URB	Yes
Shahbaz et al. (2013a, 2013b)	1980–2010	Romania	ARDL	CO_2, EC, GDP, GDP^2	Yes
Tiwari et al. (2013)	1966–2011	India	ARDL	CC, CO_2, GDP, TO	Yes
Shahbaz et al. (2014)	1971–2010	Tunisia	ARDL, VECM Granger	CO_2, EC, GDP, GDP^2, TO	Yes
Shahbaz et al. (2015)	1971–2008	Portugal	ARDL	CO2, EC, GDP, TO, URB	Yes
Al-Mulali et al. (2015a, 2015b)	1981–2011	Vietnam	Fixed effect (FE) GMM	CP, GDP, LF, TO	Yes
Dogan and Turkekul (2016)	1960–2010	USA	ARDL, Granger	CO_2, FD, GDP, GDP^2, TO, URB	No
Katircioglu, Katircioglu et al. (2018)	1960–2013	Turkey	Panel data	CO_2, EC, FP, GDP, RER	Yes
Destek et al. (2018)	1980–2013	EU	Panel data	EC, EFP, GDP, GDP^2, TO	Yes

CC coal consumption, *CO_2* carbon dioxide emission, *CP* capital, *EC* energy consumption, *EFP* ecological footprint, *FD* financial development, *FP* fiscal policy, *GDP* gross domestic product, *IS* industry structure, *LF* labor force, *OG* output growth, *RER* real exchange rate, *URB* urbanization, *TO* trade openness

energy demand rises, leading to an increase in greenhouse gas emissions (Katircioglu and Katircioglu 2018a, 2018b).

Urbanization resulted in social and economic consequences in many countries, especially in developing areas, which also leads to economic development. That is, there is a new demand for more products and services as the population grows in large cities. Most of the time, developing countries are unable to meet these requirements in an environmentally friendly manner. Therefore, to contemporary EKC models, urbanization is added as it has an impact of polluting the environment (Abid 2015; Dogan and Turkekul 2016; Du et al. 2012; Shahbaz et al. 2015). On the other side, Katircioglu and Katircioglu (2018a, 2018b) pointed out that fuel oil and other traditional sources of energy are the primary reasons behind carbon dioxide emissions that are closely linked to urban development.

As a consequence of the rapidly growing polluting sectors such as manufacturing, industry, and trade, scholars tend to investigate the effects of such segments, for example, like overall trade activities on environmental quality (Destek et al. 2018; Dogan and Turkekul 2016; Katircioglu et al. 2014; Tiwari et al. 2013; Du et al. 2012; Shahbaz et al. 2012). Studies find that trade activities exert statistically significant effects on environmental quality in many countries. Developing countries might have a comparative advantage over developed countries in the sectors which result in pollution. On the other hand, developed countries focus more on service and light manufacturing sectors. Based on their stage of growth, the distinction between these two nation blocks enables them to differ their financial structure, which generates composition effect, and Pollution Haven Hypothesis (PHH) can explain this phenomenon. Liberal trade theories indicate that nations choose to produce goods which they have a comparative advantage. Due to differences in environmental norms between countries, products that require dirty production processes cannot be delivered by those that apply stricter ecological standards. They are thus shifting their sectors of this form to countries that do not have rigid environmental regulations. Pollution haven is regarded as the country that becomes a center of attraction for dirty production industries. In the relevant sectors, if pollution havens tighten their pollution norms, net exports and net incoming foreign direct investment (FDI) will drop.

On the other hand, when multinational companies transfer their cleaner technologies to the target countries, FDI inflows and environmental pollution may have an adverse interaction. This impact is called the "Pollution Halo Hypothesis" (Balsalobre-Lorente et al. 2019). Cole et al. (2008) and Tamazian et al. (2009) indicate that attracting FDI could benefit countries to improve their environmental norms by transferring cleaner technologies to their home countries.

Some recent studies focus on the impact of other economic activities on environmental degradation, such as the industry structure (Du et al. 2012), capital and labor force (Al-Mulali et al. 2015b), and financial growth (Dogan and Turkekul 2016).

Shadow economic activities also affect environmental issues, primarily in developing countries. There are, however, not many studies on the linkage between the shadow economy and environment nexus. To name a few, theoretical studies like Baksi and Bose (2010) and Chaudhuri and Mukhopadhyay (2006) examined the efficacy of shadow economies' environmental legislation. Their findings show that the more pressure being applied to companies to produce more environmentally friendly leads them to shift their manufacture more to informal sectors to save potential expenses. It is also suggested that governments will not be able to implement new efficient environmental policies without dealing with the shadow economic activities (Biswas et al. 2012).

The existing literature lacks an empirical analysis investigating the effect of shadow economic activities on the environmental quality of Turkey using aggregate data. This study is the first effort to the best of our knowledge to fill this gap by incorporating aggregate shadow economic activities into the current EKC structure by using the dependent ecological footprint variable that is thought to be a better measure to represent environmental degradation in an example of a developing country, Turkey.

Model specification and data

Model specification

The main idea behind this study is that the determinants of environmental pollution are both formal and informal (shadow) economies. Energy consumption is also included in the model as a driving factor for environmental pollution (Heidari et al. 2015). Besides, as suggested by many scholars in the empirical literature (Kalayci and Koksal 2015; Katircioglu et al. 2014), trade openness, financial growth, urbanization, and real exchange rate are added as control variables to our model knowing that they are essential drivers of formal and informal economic activities (Imamoglu et al. 2018). Therefore, Eq. (1) presents an empirical model of this study under the EKC framework:

$$EFP_{it} = \beta_0 + \beta_1 GDP_t + \beta_2 GDP2_t + \beta_3 EC_t + \beta_4 FD_t + \beta_5 TRD_t + \beta_6 URB_t + u_t \quad (1)$$

where EFP denotes ecological footprints, GDP denotes the official economy, GDP^2 denotes square of GDP, EC denotes energy consumption, FD denotes financial development, TRD denotes trade volume, and URB denotes urbanization.

Table 2 Descriptive statistics of variables

	lnGDP	lnEFP	lnEC	lnFD	lnRER	lnSE	lnTO	lnURB
Mean	26.463	18.575	6.748	3.686	14.239	4.174	3.245	17.054
Median	26.521	18.624	6.818	3.588	14.125	4.192	3.477	17.177
Maximum	27.656	19.351	7.369	4.364	14.702	4.361	4.007	17.846
Minimum	25.203	17.614	5.954	3.194	13.879	3.785	2.120	16.016
Std. Dev.	0.678	0.514	0.402	0.290	0.261	0.122	0.630	0.565
Skewness	− 0.085	− 0.205	− 0.275	0.611	0.370	− 1.207	− 0.456	− 0.316
Kurtosis	1.972	1.903	2.045	2.716	1.639	4.587	1.653	1.757
Jarque-Bera	2.440	3.083	2.734	3.541	5.401	18.790	5.955	4.376
Sum	1429.0	1003.0	364.4	199.1	768.9	225.4	175.3	920.9
Observations	54	54	54	54	54	54	54	54

In an attempt to quantify the growth effects of both official and unofficial economies on environmental quality, the following model is proposed in the logarithmic structure (Katircioglu 2010):

$$ln\ EFP_t = \beta_0 + \beta_1 lnGDP_t + \beta_2 lnGDP2_t + \beta_3 lnEC_t + \beta_4 lnFD_t + \beta_5 ln\ TO_t + \beta_6 ln\ SE_t + \beta_7 lnURB_t + \beta_8 lnRER_t + u_t \quad (2)$$

where TO denotes trade openness, SE denotes the shadow economy, and RER indicates the real exchange rate. Also β_1, β_2, β_3, β_4, β_5, β_6, β_7, and β_8 are the coefficients of the regressors, and lastly, u_t stands for the error term.

Data

In this study, annual data spanning from 1961 to 2014 are used in an attempt to investigate the impact of official and unofficial economies on Turkey's environmental degradation. The variables used in this analysis are:

The ecological footprints (EFP); the official size of the economy (GDP; real GDP measured in 2010 constant USD), the shadow economy representing the unofficial size of the economy (SE), energy consumption (EC; kt of oil equivalent), trade openness (TO; international trade as of GDP), financial development index (FD), urbanization population as share of total population (URB), and real exchange rate (RER). GDP, EC, TO, and URB are taken from World Bank (2019), FD is taken from IMF Financial Development Index Database (IMF Database 2019),

Table 3 Phillips-Perron unit root test

	Statistics (level)			Statistics (first difference)			
	PP_T	PP_I	PP_N	PP_T	PP_I	PP_N	Conclusion
lnEC	− 2790 (0.206)	− 1.580 (0.481)	4.816 (1.000)	− 7.028 (0.000)	− 6.981 (0.000)	− 5.277 (0.000)	I (1)
lnEFP	− 2.638 (0.235)	− 1.550 (0.500)	5.944 (1.000)	− 19.755 (0.000)	− 14.613 (0.000)	− 8.629 (0.000)	I (1)
lnFD	− 1.540 (0.802)	− 0.313 (0.976)	3.079 (0.999)	− 7.475 (0.000)	− 7.359 (0.000)	− 6.589 (0.000)	I (1)
lnGDP	− 3.066 (0.124)	− 0.656 (0.848)	8.499 (1.000)	− 6.976 (0.000)	− 7.028 (0.000)	− 3.636 (0.000)	I (1)
$lnGDP^2$	− 2.978 (0.147)	− 0.392 (0.902)	8.397 (1.000)	− 6.975 (0.000)	− 7.044 (0.000)	− 3.667 (0.000)	I (1)
lnRER	− 1.576 (0.789)	− 1.735 (0.408)	− 0.075 (0.653)	− 6.142 (0.000)	− 6.121 (0.000)	− 6.179 (0.000)	I (1)
lnSE	− 1.241 (0.891)	− 0.914 (0.776)	− 0.738 (0.391)	− 8.709 (0.000)	− 7.915 (0.000)	− 7.869 (0.000)	I (1)
lnTO	− 2.262 (0.446)	− 1.006 (0.744)	1.060 (0.922)	− 5.888 (0.000)	− 5.954 (0.000)	− 5.930 (0.000)	I (1)
lnURB	− 1.224 (0.898)	− 1.550 (0.500)	− 8.916 (1.000)	− 7.015 (0.000)	− 6.440 (0.000)	− 6.898 (0.000)	I (1)

Numbers in brackets are MacKinnon (1996) one-sided *p* values. PP_T refers to the Philips-Perron unit root test with the trend, PP_I refers to the test with intercept, and PP_N refers to the test without trend and intercept (none). The spectral estimation method is the Bartlett kernel, and the Newey-west bandwidth is selected as 3

RER is taken from Turkish Statistical Institute (TÜİK 2019), SE is computed by the authors using the MIMIC (multiple causes and multiple indicators) approach by following similar strategy and modeling approach in the studies of Imamoglu et al. (2018) and Imamoglu (2016). This study, similar to those studies, uses direct taxation, indirect taxation, unemployment, social security contributions, and self-employment rates as cause variables, while real GDP per capita and the labor force participation rate are used as indicator variables to compute the size of informal economy as percent of GDP. Finally, EFP is taken from Global Footprint Network (2018a, 2018b, 2019). The descriptive statistics of the variables are provided in Table 2.

Econometric methodology

Based on the theoretical model for the period between 1961 and 2014, the formulation of the hypotheses are as follows:

H1: The shadow economy precedes significant changes in the levels of ecological footprints in Turkey.
H2: The EKC hypothesis holds for Turkey.
H3: EC, URB, FD, RER, and TO precede significant changes in the levels of ecological footprints in Turkey.

Firstly, unit root tests are carried out for all the variables of interest to check their integration levels. And then secondly, the Johansen cointegration test is then carried out to investigate the existence of cointegration in Eq. (2). Then, Eq. (2) is estimated using the vector error correction mechanism under the Johansen methodology.

Empirical results

Unit root test results

Unit root tests using the Phillips-Perron approach are carried out to decide on the integration level of series. Table 3 presents that all variables are not stationary at their level forms but become stationary at their first differences. Thus, as they are integrated of the same order, the Johansen cointegration test would be suitable for inferring the cointegration relationship in Eq. (2).

Model estimation with cointegration results

The first model tests the conventional EKC hypothesis. The dependent variable is lnEFP, and GDP and GDP^2 are independent variables. Both independent variables, as well as the overall model, are statistically significant (model 1). Then, model 1 is extended by adding other variables of interest. A total of seven models are estimated and presented in Table 3 with this respect. It is seen that the EKC hypothesis is, most of the time, confirmed for Turkey since GDP is positively significant, while GDP^2 is negatively significant (See Katircioglu 2017). In model 2 of Table 2 that coefficient of energy

Table 4 Model results

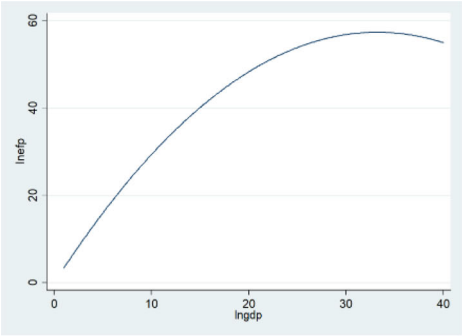
Dep.var.: lnEFP	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Intercept	36.269	95.415	36.693	− 83.886	− 156.332	56.630	234.780
lnGDP	3.454***	7.740***	3.435***	− 5.738***	− 11.440***	4.858***	19.395***
$lnGDP^2$	− 0.052***	− 0.114***	− 0.050***	0.103***	0.203***	− 0.003***	− 0.349***
lnEC		− 1.527***	0.007	0.803***	0.907**	− 0.245	− 1.235***
lnFD			− 0.067**	− 0.015	0.062	0.164***	0.185***
lnURB				0.524***	1.045**	0.372**	0.186
lnRER					− 4.056***	− 0.18***	− 0.118**
lnTO						0.158***	0.476***
lnSE							1.008***
Lag order	2	5	3	1	1	2	2
Cointegration	yes	yes	yes	yes	yes	yes	yes
R square	0.424	0.589	0.744	0.402	0.412	0.738	0.665
BG LM test	0.5713	0.6561	0.1851	0.3912	0.5292	0.5687	0.3013
White test	0.0874	0.5034	0.2498	0.2025	0.1897	0.3172	0.2201
ECT_{t-1}	− 0.955***	− 0.804**	− 0.583***	− 0.507***	− 0.282**	− 0.431***	− 0.716***

BG LM test refers to Breusch Godfrey LM to test the autocorrelation of the models. The white test is conducted to test the heteroscedasticity of the models

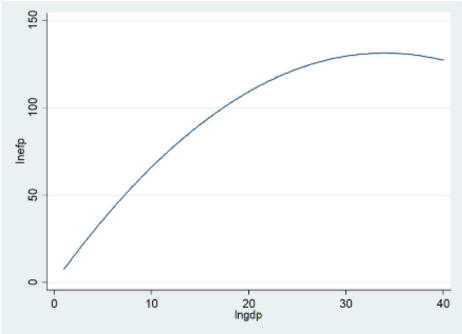
*The rejection of the null hypothesis at the 10% level

**The rejection of the null hypothesis at the 5% level

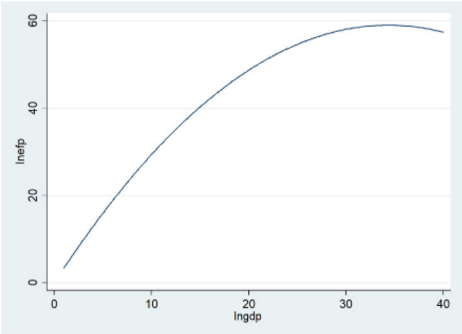
***The rejection of the null hypothesis at the 1% level



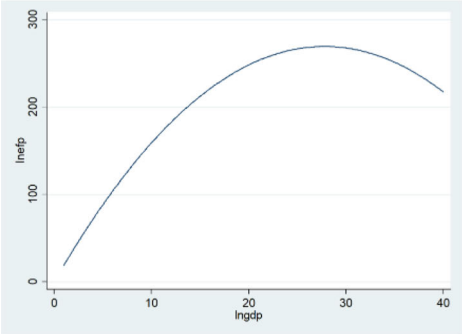
(a). EKC model 1



(b). EKC model 2



(c). EKC model 3



(d). EKC model 7

Fig. 2 Estimated EKC Models

consumption (EC) is negatively significant; but, it is seen in models 4 and 5 that financial system (FD) and urban development (URB) moderates the effects of energy consumption on ecological footprint positively which the related coefficients of EC are statistically significant. However, in model 7, when the size of the SE is added to regression, the coefficient of energy consumption becomes again negatively significant. In model 7, it is seen that shadow economy exert positively significant effects on the volume of ecological footprint which is reasonable and its coefficient is elastic ($\beta = 1.008$, $p < 0.10$). Again in model 7, it is observed that the financial system and foreign trade activities exert positively significant effects on the volume of ecological footprint while urban development does not have any significant effect. Diagnostic test results in Table 4 exhibit that estimations do not suffer from any econometric deviation such as autocorrelation and heteroscedasticity. Furthermore, error correction terms (ECT), which show convergence between short-term and long-term values of ecological footprint are considerably high, negative, and statistically significant. In all of the models in Table 4, cointegrating vectors using the Johansen methodology is also confirmed.

The findings of this study are consistent with the results of Cetin et al. (2018b), Gokmenoglu and Taspinar (2016), Halicioglu (2009), Ozturk and Acaravci (2013), Pata (2018), and Yavuz (2014). This study does not, however, confirm the findings of Cetin et al. (2018a, 2018b), Katircioglu and Katircioglu (2018a, 2018b), which indicated that urbanization would result in higher emissions.

Figure 2 plots the behavior of the EKC, including the basic EKC (model 1) and models 2, 3, and 7 demonstrating the inverted U shape confirming the conventional EKC framework. Although all the plots show similar trends regarding the EKC structure, the EKC model estimate is drawn in Fig. 2d gave a better EKC plot where estimated EFP increases to a rate where it reaches a peak point and then starts moving horizontally and then declines as in the traditional EKC model.

The highest point, according to the actual EKC graph, was in 2012 when GDP per capita was $11,720, and with the rise in GDP per capita in 2013 and 2014 to $12,542 and $12,127 (World Bank 2019), the plot first decreased and then shifted horizontally. Turkey, however, was unable to maintain its per capita GDP increase and suffered a sharp decline to points below $11,000 after 2014 (World Bank 2019), which was mainly due to the rapid depreciation of its domestic currency, Turkish Lira. This situation can be explained with the term middle income trap related to some structural economic problems. Therefore, it is expected that until the peak point is climbed over, the EKC plot will not offer an inverted U shape. The findings are parallel with those studies of Katircioglu (2014b), Katircioglu and Taspinar (2017) in the case of Turkey.

Models 4, 5, and 6 do not bring us familiar shapes in Fig. 2 because when the URB variable is added to the equation, FD becomes statistically insignificant. Nevertheless, all variables except URB are statistically significant after the SE variable has been included in the model.

According to model 7, the turning point was found as 27.07. The highest lnGDP value was 27.65, so we can conclude that in this model, Turkey has hit the turning point stage. As an explanatory variable, model 7 used shadow economies in the model. This result demonstrates how important it is to have shadow economies in the model as the inverted U curve closes to the *X*-axis meaning that environmental pollution starts to decrease as GDP continues to rise.

Conclusion

Many previous studies are based on official macroeconomic data for the nexus of environmental degradation and economic growth. There are quite a few studies in the literature investigating this relationship, taking into account shadow economies as well as formal economies and environmental pollution. To the best of our knowledge, this study is the first of its kind for this nexus using ecological footprint data.

Therefore, this study seeks to fill this gap by investigating the role of shadow economies in ecological footprint levels for the case of Turkey.

The results of this study reflect the long-term positive effect of shadow economic activity on Turkey's ecological footprint levels. This research, therefore, draws an important conclusion that in the case of Turkey, shadow economies are long-term and significant generators of environmental pollution. Results also show that financial development and trade openness exert positively significant effects on the volume of ecological footprint, while urbanization does not exert any significant impact.

Shadow economies have an essential place in their economies, especially in developing countries. In the light of this study, given the enormous and statistically significant impact of shadow economies on environmental degradation, the government must try to cope with these illegal activities not only because of the tax loss but also because of their apparent adverse ecological effects. Another policy recommendation would be to enact laws that will impose a polluter pay mechanism on the polluting industries and support environmental friendly sectors and technologies.

More research can be carried out using other macroeconomic variables that emphasize the role of shadow economies in environmental degradation for Turkey and other developing countries.

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